Irrigation Scheduling Studies using a Linear Irrigation System

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INTRODUCTION

Research and development of specialty crops is always limited by lack of resources, especially labour. Minor or new specialty crops require more labour per research plot because the crops are usually more difficult to harvest. Plots must often be weeded by hand because other weed control methods are not available. These problems are exaggerated under irrigated conditions due to increased vegetative growth per plot for both the crop and the weeds. Irrigation scheduling experiments are particularly laborious using the traditional basin method. Water application and soil moisture depletion measurements are time consuming.

This paper outlines how a low pressure linear move irrigation system at the Saskatchewan Irrigation Development Centre (SIDC) is used to conduct experiments for irrigation scheduling and assessing plant disease interactions with irrigation. Knowledge of the crop responses to irrigation is basic to determining crop suitability for irrigated production. Data from current studies involving fenugreek, coriander, broadbean, dry bean, field pea and grass pea are used as examples. These crops are new or potential specialty crops in Saskatchewan.

The linear move irrigation system was installed at SIDC in 1986. It was specially designed for irrigation scheduling studies by incorporating shutoffs on each sprinkler. The sprinklers were placed on drops to improve application efficiency. The field it covers is divided into six sub-fields of approximately 5 acres as shown in Figure 1. One is designated for specialty crop research each year. Two spans of the system cover one sub-field. Twenty ranges running north and south are established for experimental plots. Individual nozzle control allows the sub-field to be arranged as irrigation treatments (Figure 2) separate blocks arranged by crop. Within each crop block, moisture gradients are established. Rain gauges are established in each range within a block to allow water application measurement at the top of the canopy. Neutron tubes can be installed before seeding if necessary. A typical seasonal water application profile is shown in Figure 3. Absolute control of the amount of water application is not possible. However, the system can be used to simulate the crop canopy conditions expected under a centre pivot system.

MOISTURE GRADIENT EXPERIMENTS

A regression analysis is used to determine the effect of irrigation on yield or other crop characteristics. Rain gauges are monitored so that data are recorded after each precipitation or irrigation event. The total seasonal water application is considered to be an independent variable. For very little cost, a yield response curve can be determined for a minor crop, for example, coriander. Plots are sown across all twenty ranges and yield is recorded for each plot. This simulates a range of moisture environments. Adding a seeding date treatment would sample an even greater range of environments. Access to the plots at harvest is easy because the dryland treatments at either end are usually harvested first. In the case of coriander in 1990, a positive linear response to irrigation was observed (Figure 4).

The 1990 yield response to irrigation for fenugreek, a leguminous spice crop, is shown in Figure 5. In this example, an additional comparison was possible because the experiment was laid out as twenty randomized complete blocks of two entries. Fenugreek showed no response to irrigation although the Agriculture Canada Morden selection NC109-1 outperformed 'Australian'. Total dry matter showed a positive response to irrigation (Figure 6) while the harvest index response was negative (Figure 7). The conclusion was reached that fenugreek is either better suited to dryland or susceptible to a late-season disease (Sclerotinia or late root rot) that restricts a yield response to irrigation.

A third scheduling experiment in 1990 compared the yield response to irrigation for Chinese broadbean, Outlook fababean, and four lines derived from a cross between the two. Consistent positive linear response to irrigation was observed (Figure 8, only one of the four derived lines presented). A basin irrigation experiment conducted in 1990 showed similar results. The cost of the linear experiment in terms of labour is estimated at about 50% of that of the basin experiment which could accommodate only a single cultivar. Valuable additional information was obtained regarding the relative performance of Chinese broadbean compared to fababean under a range of moisture conditions.

A fourth example is a moisture gradient experiment involving dry bean in 1990. The original objective of this experiment was to construct a yield response curve comparing Viva pink bean and Topaz pinto bean. Under disease free conditions, the response of dry bean to irrigation can easily result in a doubling of potential yield. However, extremely favourable conditions for Sclerotinia development occurred in late July 1990. These plots were not treated with a fungicide. It was obvious that yield would be affected. Instead of abandoning the experiment, yield measurements and Sclerotinia ratings were recorded to obtain information on potential dry bean yield loss attributable to this disease (Figure 9). The potential for infection was assumed to be constant across the field because uniformly irrigated canola and other susceptible crops were grown on this field within the last four years. The infection response by Sclerotinia to increased irrigation is shown in Figure 10.

Figure 1. Linear Irrigation Field Layout

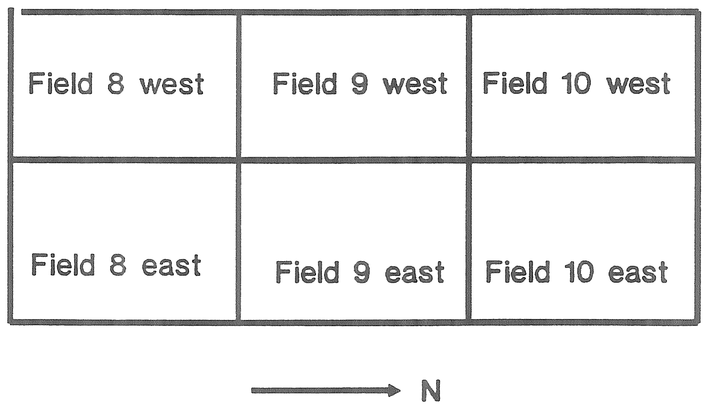


Figure 2. Linear Irrigation System Basic Plot Design

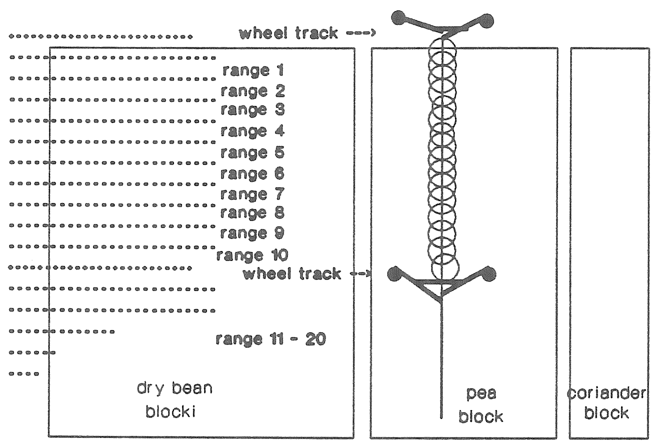


Figure 3. Seasonal Water Application Profile for Pea Block 1990

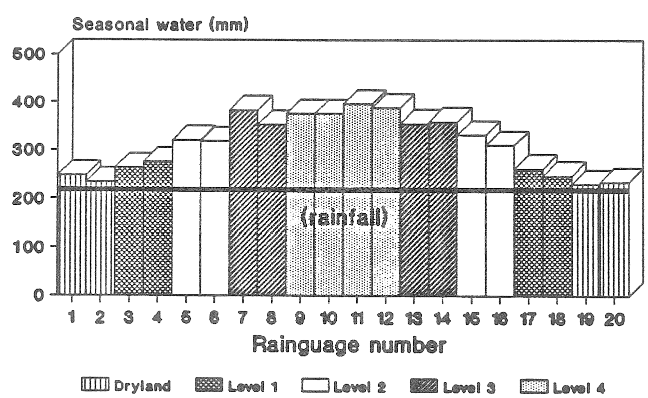
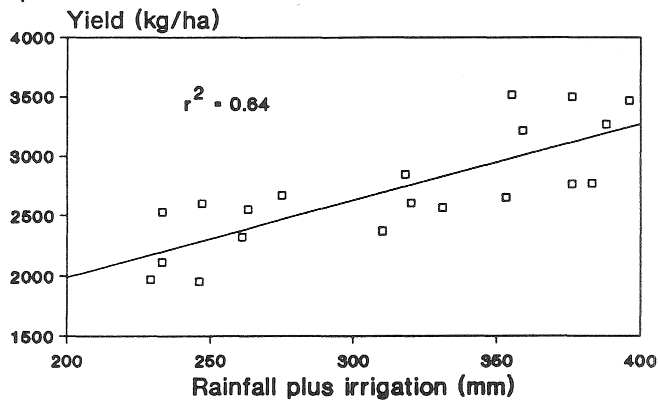
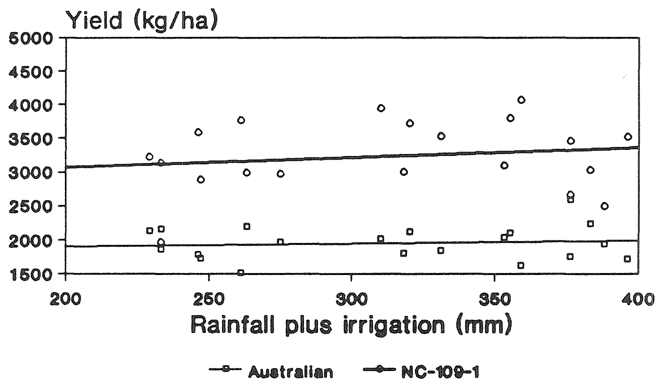


Figure 4. Regression of Yield on Water Application for Coriander



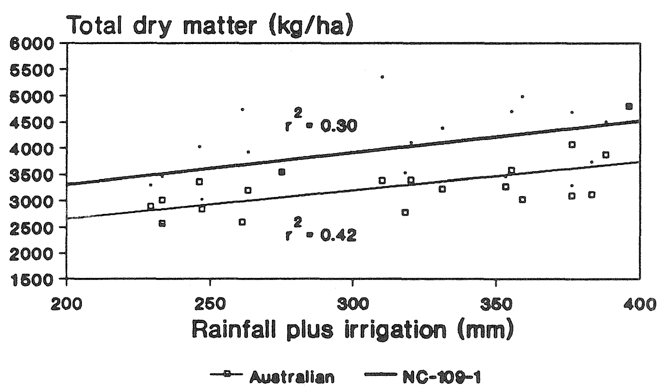
1990 at SIDC, Outlook, Saskatchewan

Figure 5. Regression of Yield on Water Application for Fenugreek



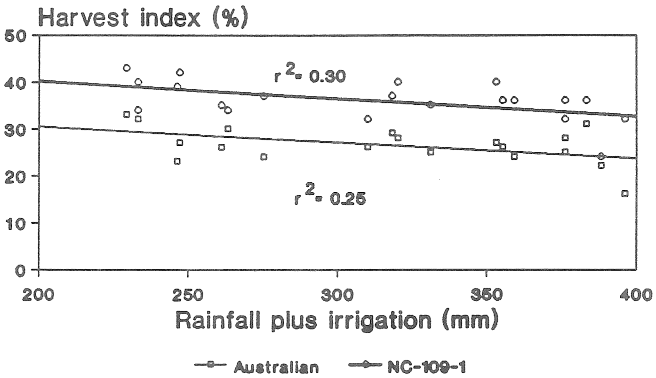
1990 at SIDC, Outlook, Saskatchewan

Figure 6. Regression of Total Dry Matter Water Application for Fenugreek



1990 at SIDC, Outlook, Saskatchewan

Figure 7. Regression of Harvest Index on Water Application for Fenugreek



1990 at SIDC, Outlook, Saskatchewan

Figure 8. Regression of Yield on Water Application for Fababean

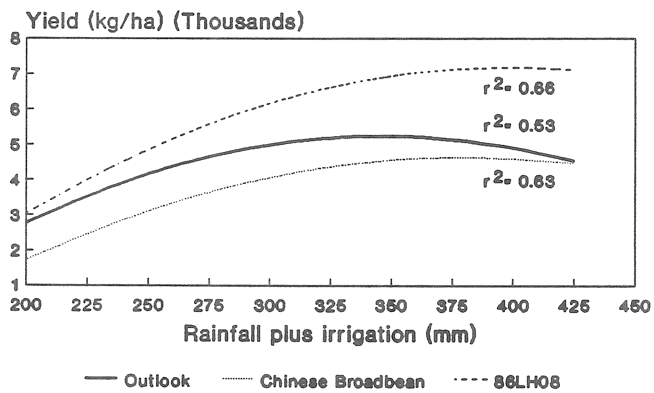
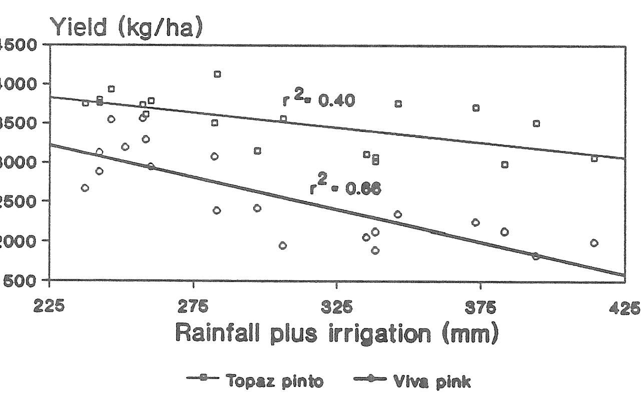
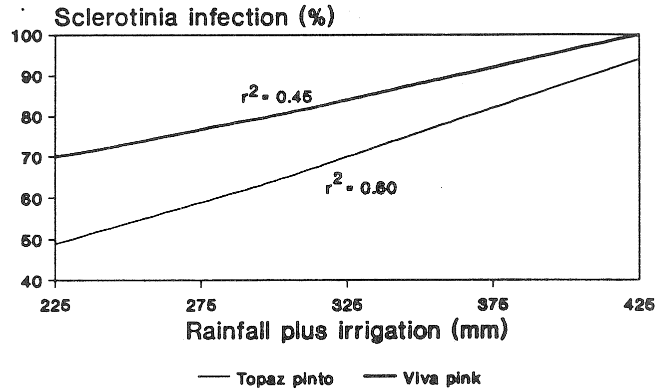


Figure 9. Regression of Yield on Water Application for Dry Bean



1990 at SIDC, Outlook, Saskatchewan

Fig. 10 Regression of % Sclerotinia
Infection on Water Application-Dry Bean



1990 at SIDC, Outlook, Saskatchewan

IRRIGATED BLOCK EXPERIMENTS

In this type of experiment, levels of irrigation are established as shown in the legend of Figure 3. In this example water application zones of dryland and four irrigation levels are available. Complete blocks of experimental treatments are laid out within selected zones. True randomization of the irrigation treatments is not possible, but this is a more practical arrangement than setting up basins, solid sets or wheel moves for factorial experiments. There is much less traffic through the plot area and border effects are minimized.

The first example of this type of experiment is shown in Table 1. One of the objectives of this experiment was to determine if interactions occurred between irrigation level, disease development (measured by response to fungicide application) and growth habit of pea cultivars. Two replications were established as a 3 irrigation level x 4 fungicide x 3 cultivar factorial experiment. Irrigation levels were three application zones as measured by rain gauges (0 - 25 mm, 75 - 100 mm and 125 - 150 mm). Fungicide treatments were three commercial dry bean fungicides and an unsprayed control. Cultivars were Express, Radley and Progreta. All are medium height. Radley is a semi-leafless green type, Progreta is a tare-leafed green marrowfat type, and Express is a yellow pea with leaf type between tare and normal.

Table 1. Analysis of variance of irrigation x cultivar x fungicide study of field pea at Outlook, Saskatchewan, 1990.

Source of variation	Degrees of freedom	Mean square	Value of F	Level of probability
		(x 10000)		
Replication	1	137.3	3.84	NS
Irrigation (I)	2	864.0	24.14	**
Cultivar (C)	2	767.4	21.44	**
Fungicide (F)	3	23.7	0.66	NS
I x C	4	33.1	1.74	NS
I x F	6	23.0	0.93	NS
C x F	6	59.4	0.64	NS
I x C x F	12	35.8	1.66	NS

The analysis of variance showed no interaction between factors, no effect of fungicide treatments and highly significant differences in yield attributable to irrigation and cultivar effects. Table 2 shows how irrigation increased yield and that Express was superior to the other two cultivars at all irrigation levels.

Table 2. Yield of three pea cultivars at three levels of irrigation in 1990 at Outlook, Saskatchewan

	Yield		
	Irrigation level		
Cultivar	0 - 25 mm	75 - 100 mm	125 - 150 mm
	kg/ha		
Radley	4228	4688	5161
Progreta	3601	5196	4873
Express	4865	5920	6208

LSD (0.05) = 372 within rows or within columns

In terms of labour requirements, a basin or conventional sprinkler experiment would require at least twice the amount of labour. The amount of useful information generated by a basin experiment of this type would be cut by more than half because fewer factors could be accommodated in a single experiment. In the case of new or minor specialty crops, this type of experiment can easily accommodate seeding rate and row spacing treatments at little extra cost.

Replication of irrigation treatments using water application zones is not always possible when a number of experiments for a diverse group of minor crops must fit in the same field. A second type of irrigated block experiment is used when space or seed supply becomes limiting. Where irrigation is not replicated, a number of randomized complete blocks of treatments is established in each water application zone. Replication is therefore confounded with irrigation.

An example of the analysis of variance used in this situation is given in Table 3, using an experiment from 1989 using grass pea.

Table 3. Analysis of variance of irrigation x breeding line interaction on BOAA content in grass pea at Outlook, Saskatchewan in 1989.

Source of variation	Degrees of freedom	Mean square	Value of F	Level of probability
		(x .0001)		
Irrigation (I)†	2	378.5	141.19	**
Reps within I	9	2.7	0.39	NS
Breeding line (B)	3	137.4	19.94	**
I x B	6	7.3	1.06	NS
Error		6.8		

† F-test for irrigation uses reps within irrigation mean square.

The seed of this drylandlegume contains the neurotoxin B-N-oxalylamino-L-alanine (BOAA). The objective of this experiment was to determine the effect of irrigation on BOAA concentration in grass pea seed, using four reduced-BOAA lines bred by Dr. C. Campbell of Agriculture Canada at Morden. The F-test for irrigation uses the mean square of the replication within irrigation effect instead of the overall error mean square. Irrigation caused a significant reduction in seed BOAA concentration (Table 4). There were also significant differences in BOAA concentration between breeding lines. It may, therefore, be prudent to select for BOAA reduction under drought conditions.

Table 4. Effect of irrigation on BOAA concentration in grass pea seed in 1989 at Outlook, Saskatchewan.

Breeding line	BOAA concentration: Irrigation treatment: Dryland	Partial	Full	Mean
	-------- mg/g of seed dry weight --------			
Nc8a-64	3.5	2.9	2.2	2.9
Nc8a-7	3.4	2.9	2.5	2.9
Nc8a-74/	2.8	2.2	1.6	2.2
Nc8a-84	2.8	2.5	2.2	2.5
Mean	3.1	2.7	2.1	
Standard error				0.1
CV = 10.0%				

Replications: 4
Seeding date: May 10, 1989
Water applied: Rainfall plus irrigation:
dryland - 95.3 mm;
partial irrigation - 225 mm;
full irrigation - 320 mm.

CONCLUSIONS

A linear irrigation system is an effective tool in specialty crop research applications. Capital costs are high but experimental operating costs are low. Moisture gradient experiments allow rapid, low-cost appraisal of crop responses to irrigation under realistic canopy situations. Irrigated block experiments allow low-cost analysis of interactions for experiments involving factorial arrangements of treatments.